NEW EUROPEAN WIND ATLAS
newa

Meso-to-microscale modelling of the ABL: an open-science approach

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Objectives of New European Wind Atlas

04/2015 – 04/2019

1. Publication of the **European Wind Atlas** database via a web interface
2. Dataset of **high-fidelity experiments**
3. Methodologies for WRA based on a **mesoscale to microscale** model-chain.
4. **V&V framework** based on the experimental campaigns and means to quantify the **uncertainties** of the wind atlas.

@mesoscale

NEWA database of mesoscale wind climate

- ✓ 30-year WRF down to 3 km resolution + downscaling to 50 m using WAsP (generalized wind)
- ✓ Mesoscale multiphysics ensemble (UQ)
- ✓ **Open source code** of the WRF configuration.

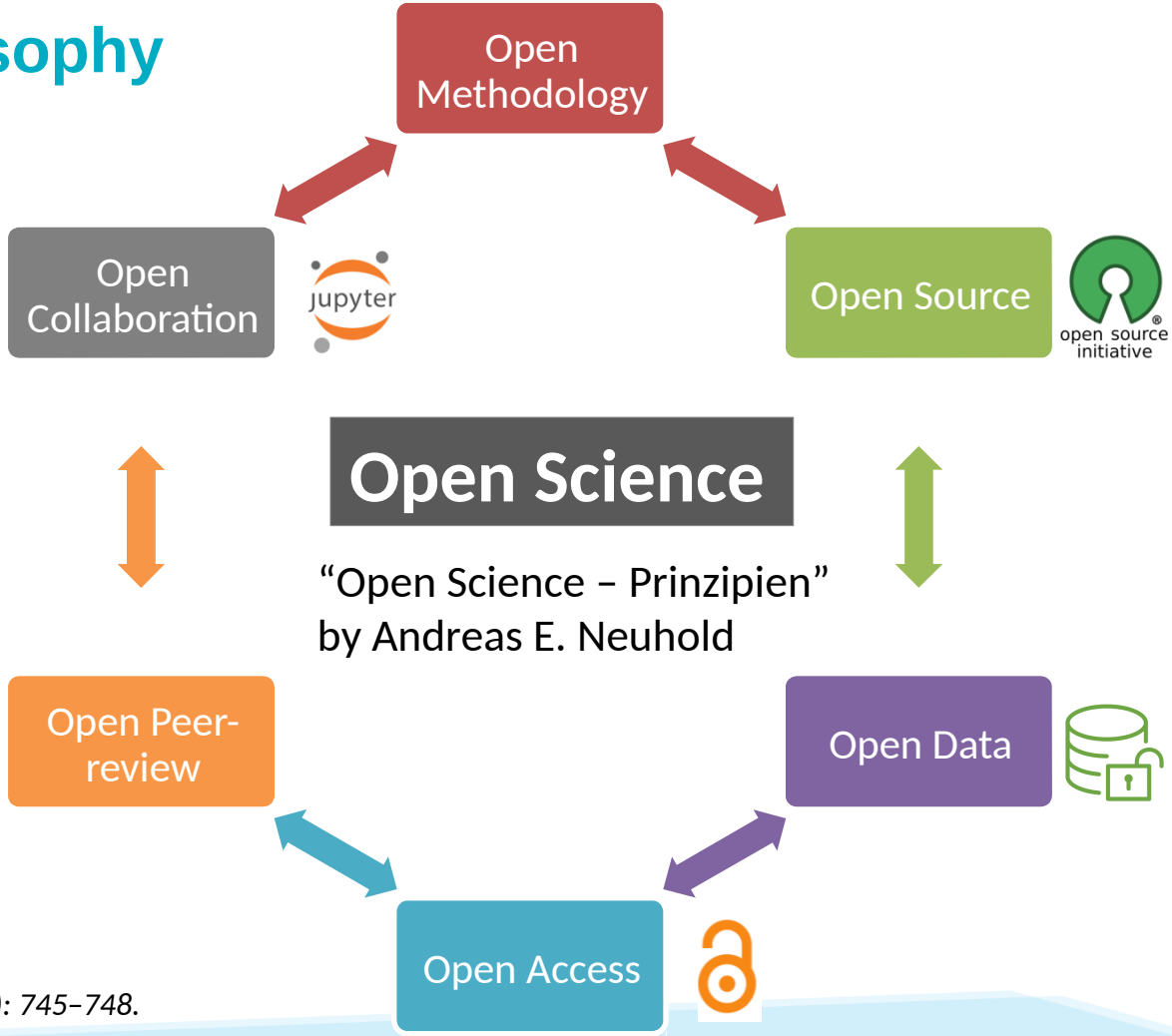
@microscale

Design methodology for CFD models (RANS or LES)

- ✓ **Open dataset** of surface-layer characterization based on aerial lidar scans of vegetation canopy
- ✓ **Open source** CFD model based on OpenFOAM (CFDWind3)

Open science philosophy

"A philosophy of making scientific research and its dissemination accessible to all levels of an inquiring society"*



Why this should be important for industry:

- **Transparency**
- **Credibility**
- **Standardization**

* *Woelfle M. et al (2011). Nature Chemistry. 3 (10): 745–748.*

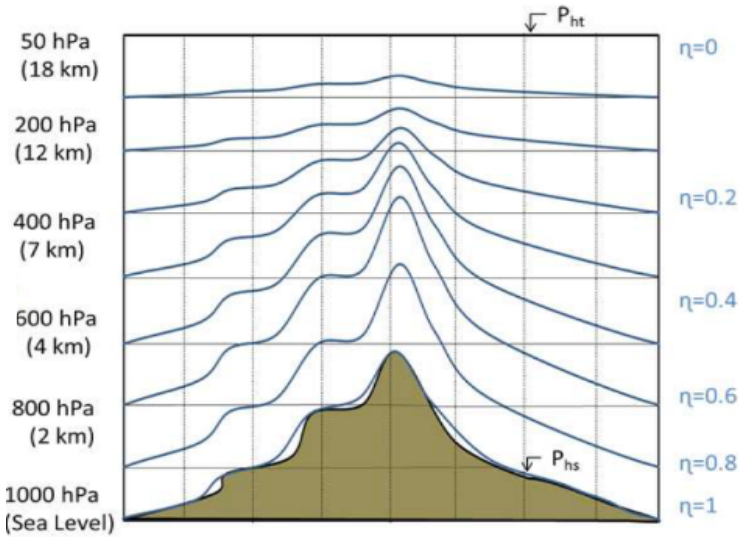
Open methodology

Challenge: Characterization of wind flow of sites with strong thermal and mesoscale variability.

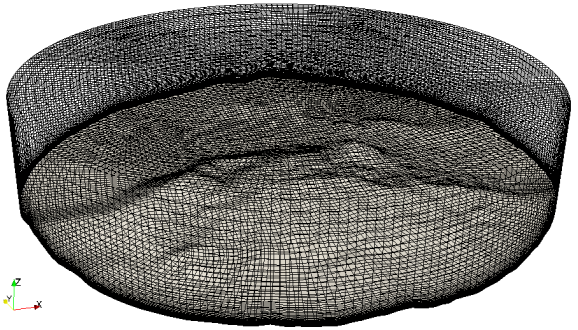
New method :

Coupling meso and microscale model through the tendencies

WRF domain



CFD domain



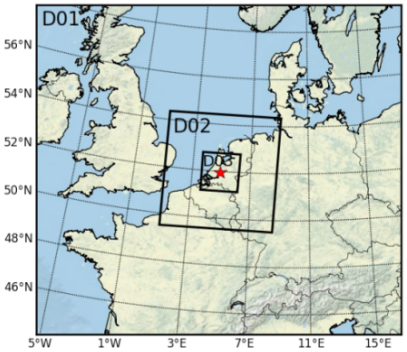
Volumetric force from WRF into CFD

$$\left(\frac{\partial P}{\partial x_i}, U_i \frac{\partial U_j}{\partial x_i}\right)$$

- *Holtslag AAM Boundary-Layer Meteorol 152 127-132*
- *Sanz-Rodrigo J, Matthew Churchfield, and Branko Kosovic. Wind Energ. Sci.(2017), 2, 35-54*

Open methodology

What are tendencies?: Volumetric forces



WRF simulation over the Netherlands for:
2006-07-01 to *2006-07-02*

Geophysical Research Abstracts
Vol. 20, EGU2018-8460-2, 2018
EGU General Assembly 2018

WRF sensitivity experiments for the mesoscale NEWA wind atlas production run

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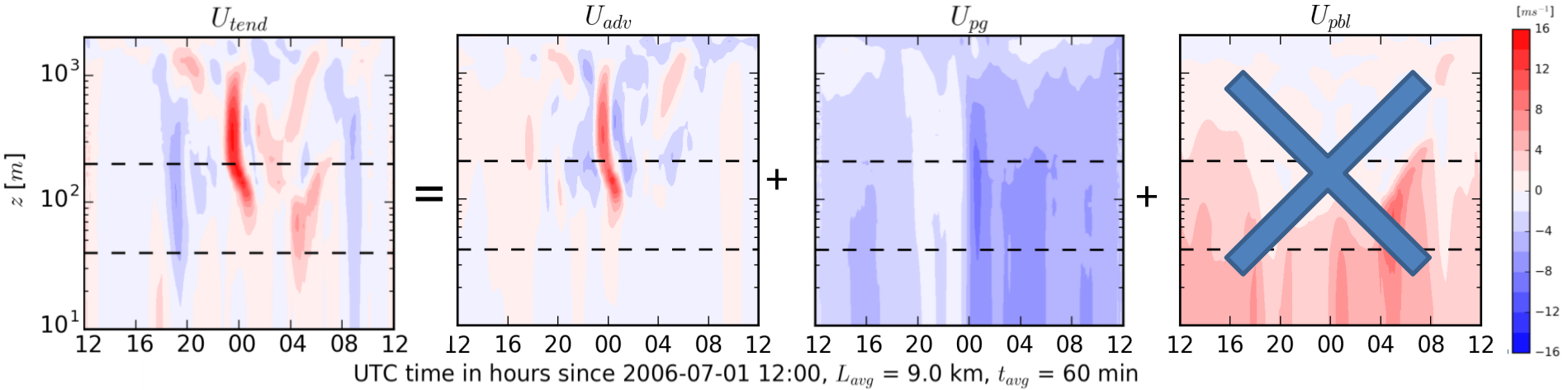
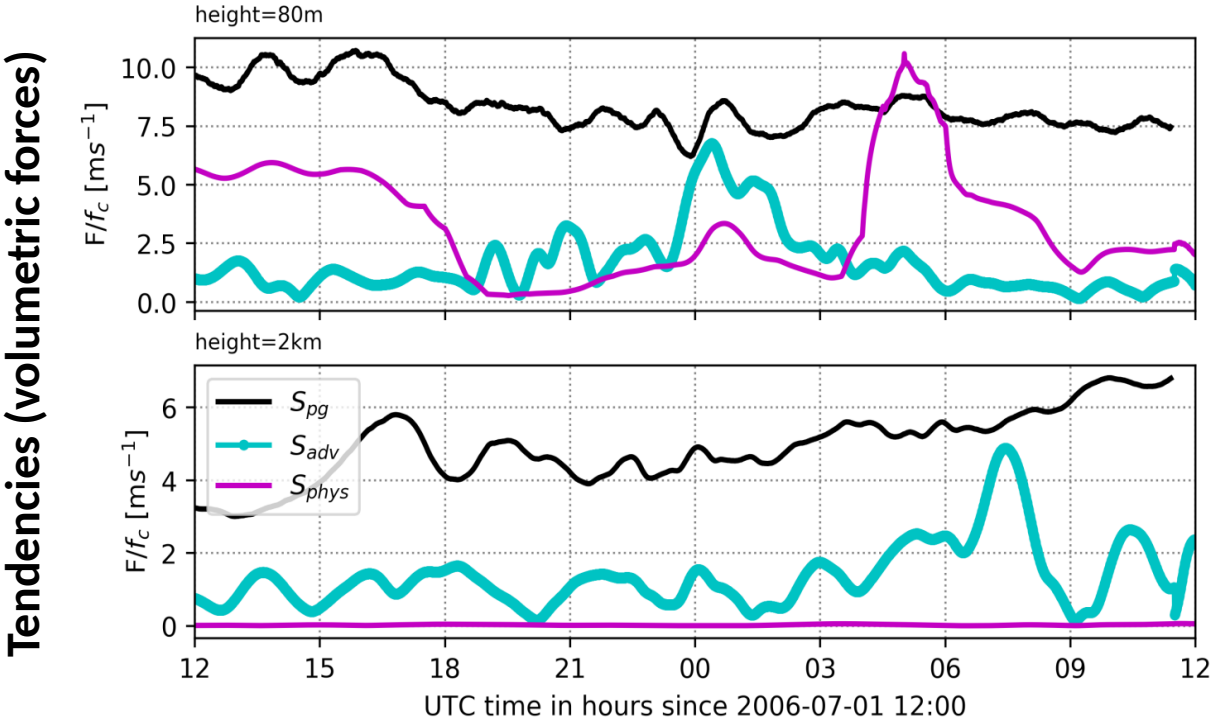
Total tendencies = Advected wind + Geostrophic wind + PBL schemes = phys



Open methodology

What are the tendencies?: volumetric forces

2006-07-01 to *2006-07-02*



Comparison between force terms of the momentum budget:

- Pressure gradient ***Spg***,
- Advective momentum ***Sadv***
- PBL parameterization term ***Sphy***

Open methodology

Open Source

Coupling method: CFDWind3

One-way offline coupling of WRF with CFD model

The CFD model

- RANS turbulent closure modified as Sogachev et al. (2012)
- Based **CENER's CFD model (CFDWind3)** built on top the Open-Source CFD tool-kit OpenFOAM
- Transient
- No humidity equation, no radiation nor phase changes

The CFD model receives from WRF:

- Pressure gradient and advective terms of momentum (Forces) and energy temperature
- Initial conditions from WRF: velocity and temperature
- Wall temperature: WRF Skin temperature

- *See Sanz-Rodrigo et al. (2017). Wind Energ. Sci., 2, 35-54, 2017*

OpenFOAM

The Open Source CFD Toolbox

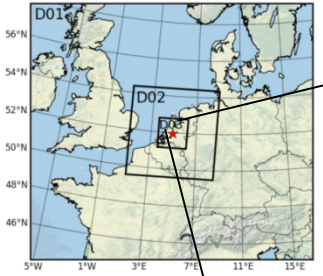
Open methodology

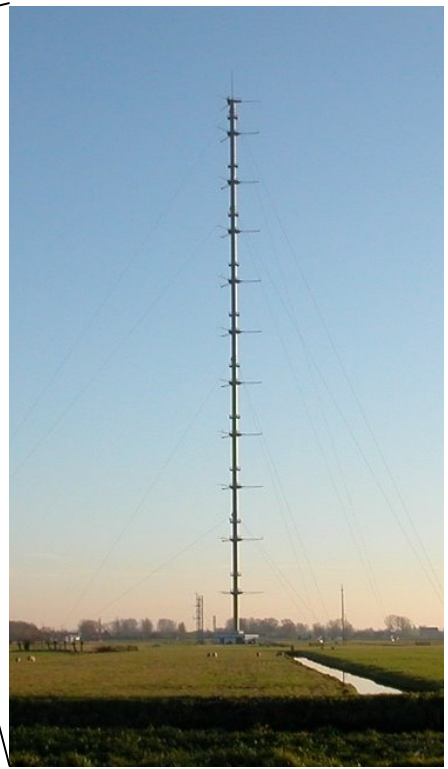
Open Source

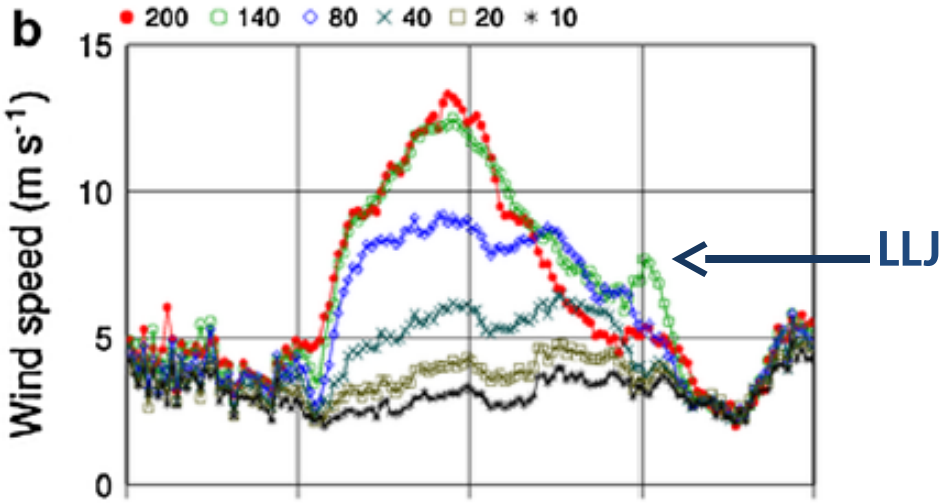
Proof-of-concept: GABLS3 diurnal cycle

GABLS3 = GEWEX Atmospheric Boundary Layer Studies

Cabauw met mast, Netherlands (*2006-07-01* to *2006-07-02*)







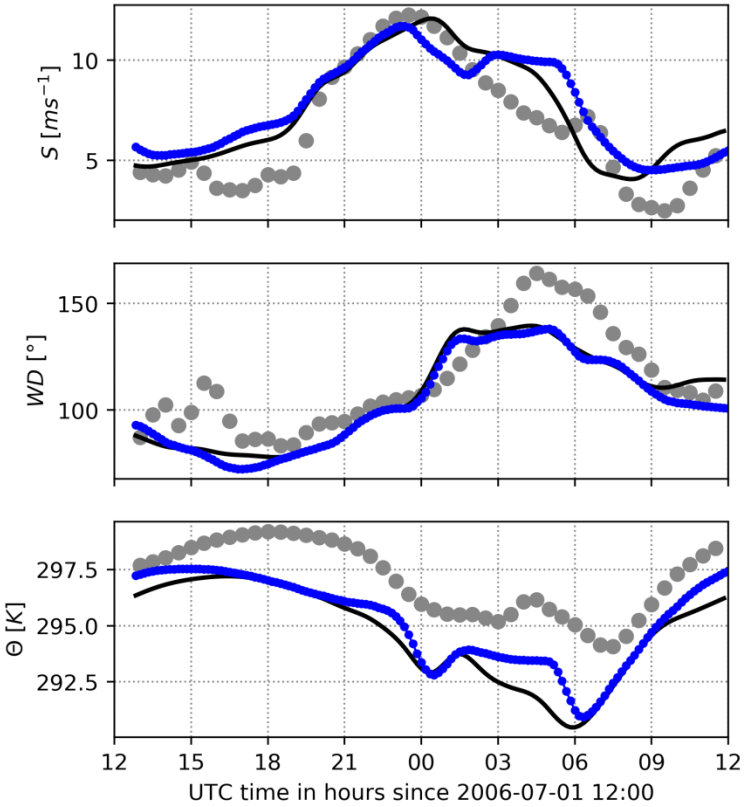
Bosveld, F.C., Baas, P., van Meijgaard, E. et al. Meteorol (2014) 152: 133

Open methodology

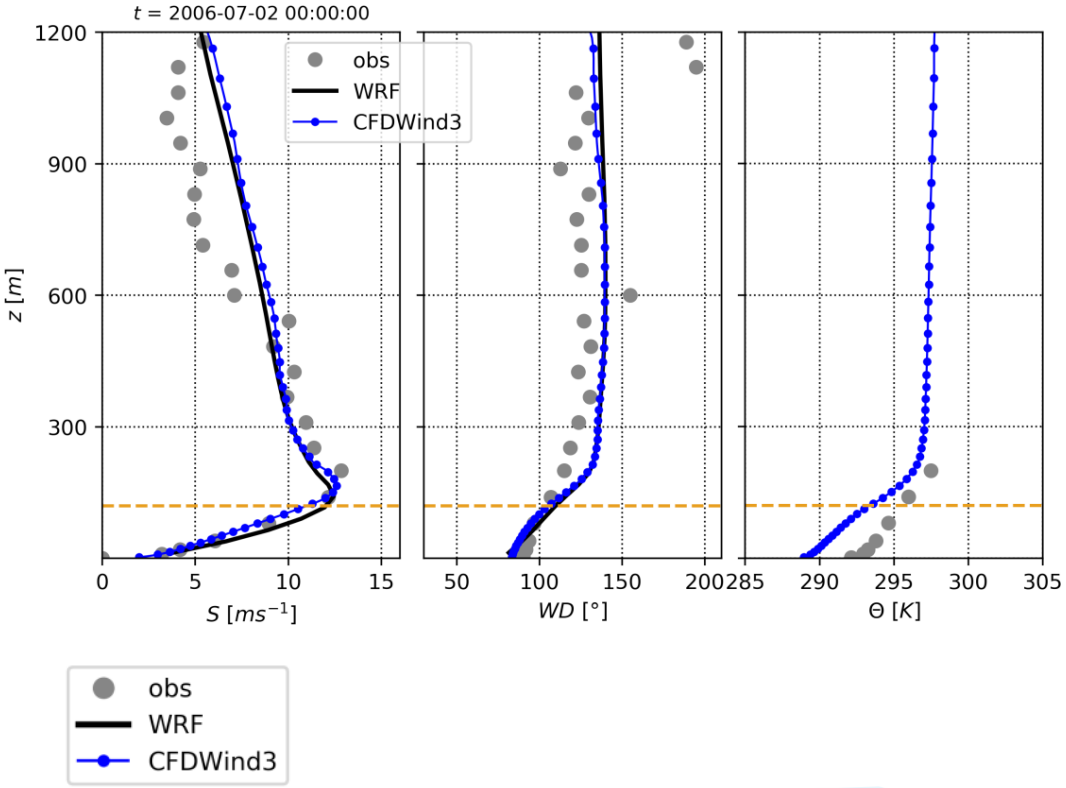
Open Source

Proof-of-concept: Results of the diurnal cycle during GABLS3 episode with CFDWind

Results at 120m above ground



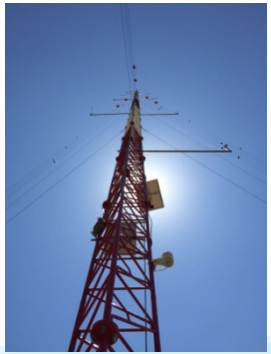
Vertical profiles



Open methodology | Open Source | Open Data

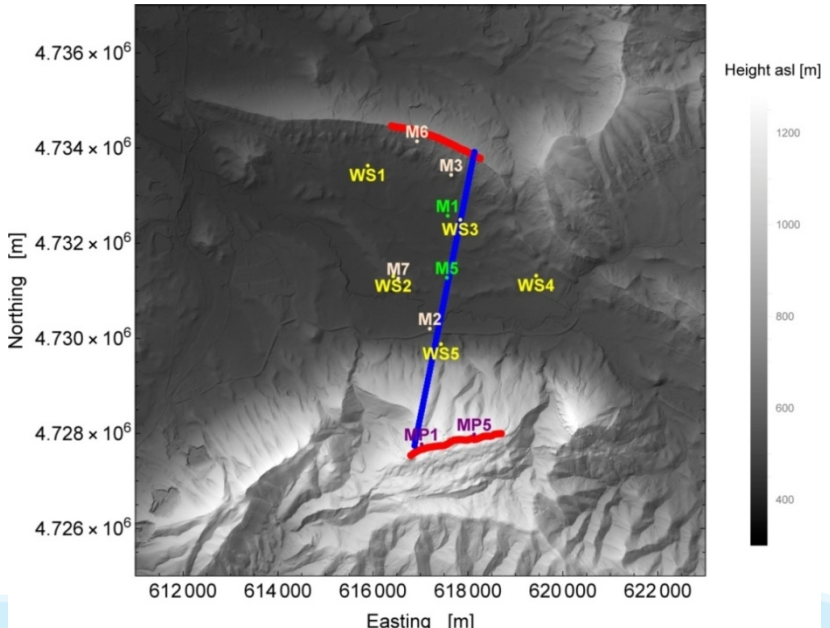
Alaiz (ALEX17) Full-Scale Experiment

- 6 month period of intensive campaign
- 12+ moth period for masts and Sodar



Measurement equipment

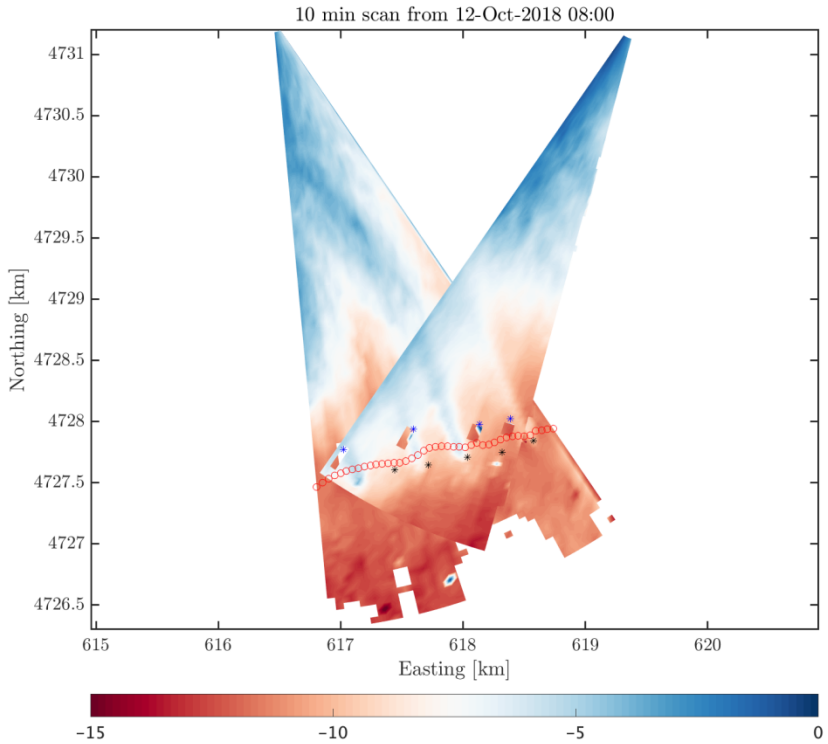
- 5 long-range scanning lidars
- 1 profiler
- 6@80m met masts (4 sonics +2 cups)
- 10 surface flux stations
- CENER's test site (4@118m masts)
- Sodar Wind-RASS



Open methodology | Open Source | Open Data

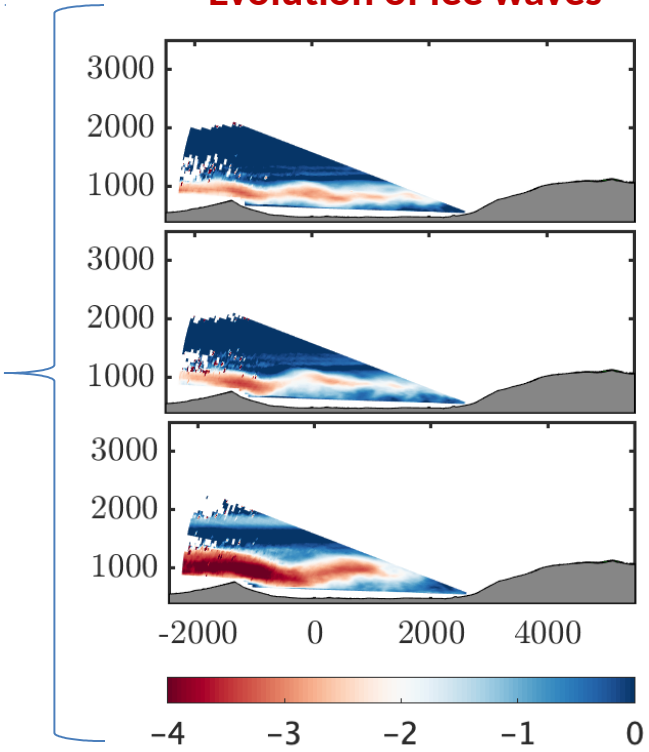
ALEX17 objectives: Better understanding of complex flow dynamics on mountain range sites.

Wind turbine wakes interaction in complex terrain



10 min scans on the 13/08/2018 7:30, 7:40 and 8:00

Evolution of lee waves



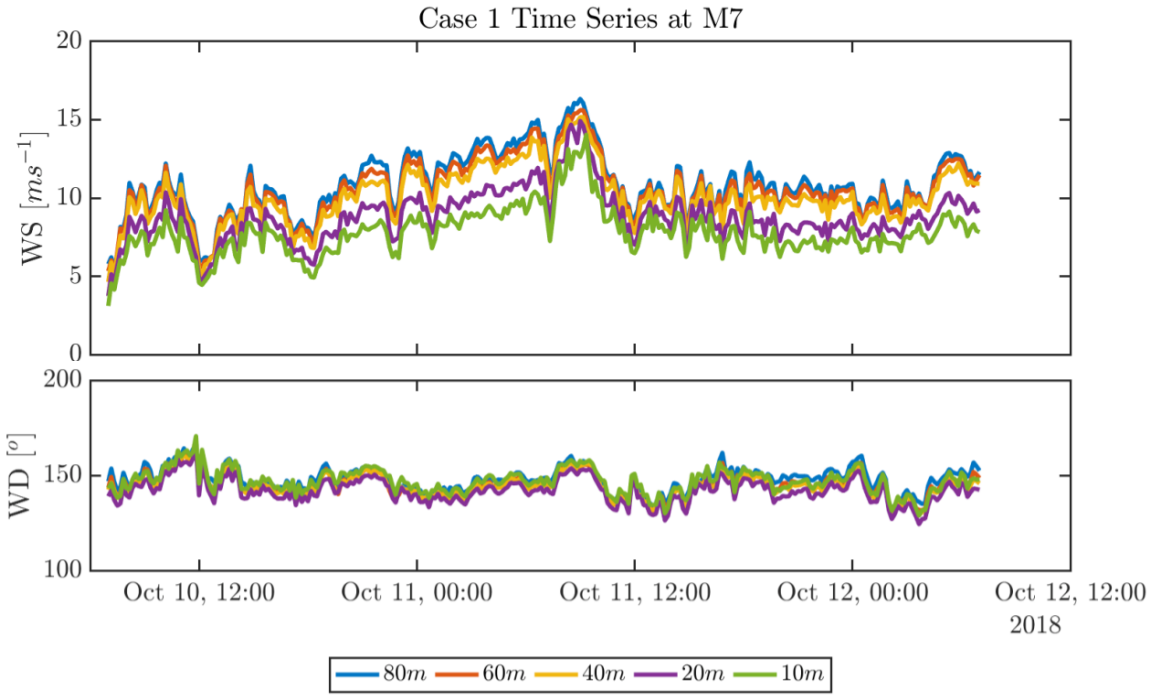
SANTOS, P. et al. (2019) ALEX 17: visualizing flow in complex terrain. WindEurope; Bilbao: 10.5281/zenodo.2620505

Open methodology | Open Source | Open Data

ALEX17 objectives: Development and Uncertainty Quantification of numerical models.

Verification & Validation of numerical models through a set of benchmarks:

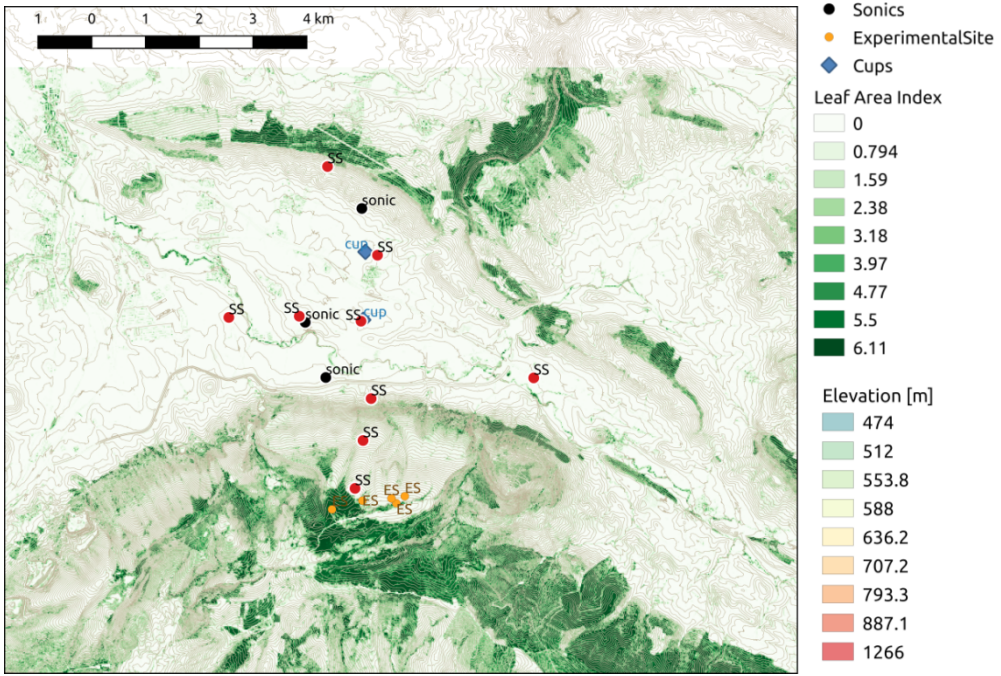
1. A particular weather episode (diurnal cycles (48h from 10-10-2018 6:00 UTC)
2. Annual integration (Jun/2018 – Jun 2019) case for AEP calculation.



Open methodology | Open Source | Open Data

Release of ALEX17 dataset in the public domain

High-resolution data of forest height and Leaf Area Density*

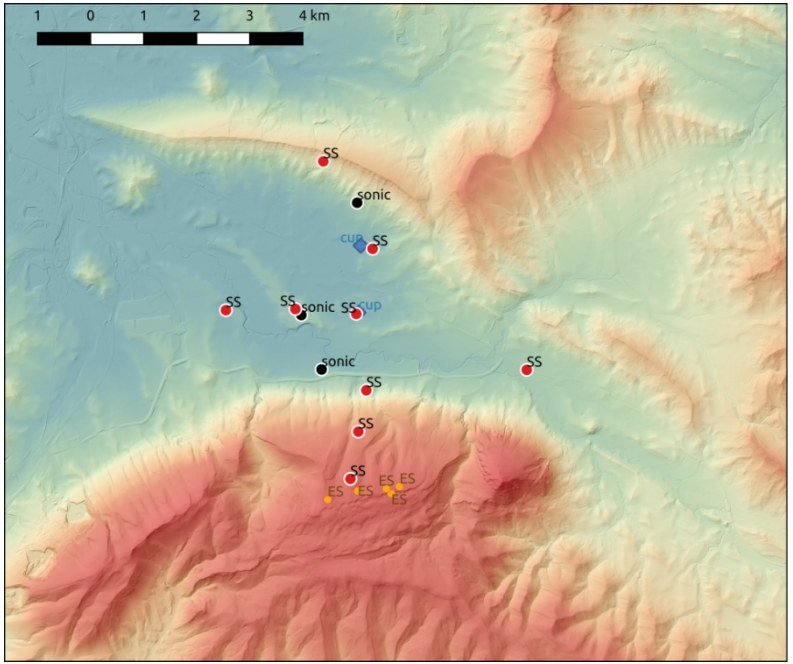


SurfaceStations
Sonics
ExperimentalSite
Cups

Leaf Area Index
0
0.794
1.59
2.38
3.18
3.97
4.77
5.5
6.11

Elevation [m]
474
512
553.8
588
636.2
707.2
793.3
887.1
1266

High-resolution (2m) data of terrain elevation*

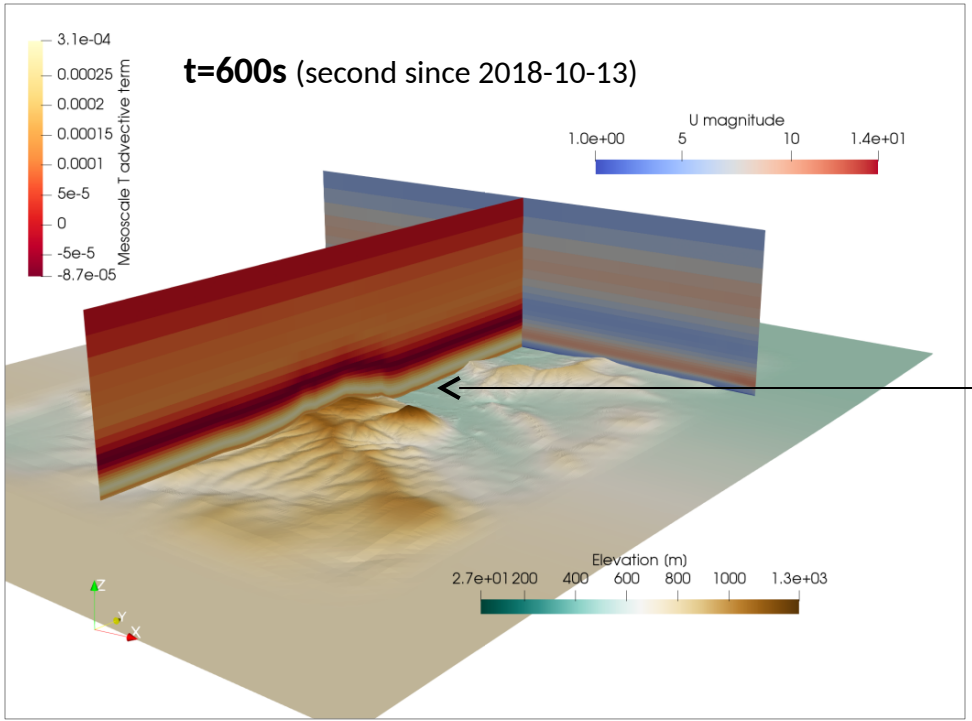


The land surface data was generated from airborne Lidar systems provided by TRACASA (https://tracasa.es)

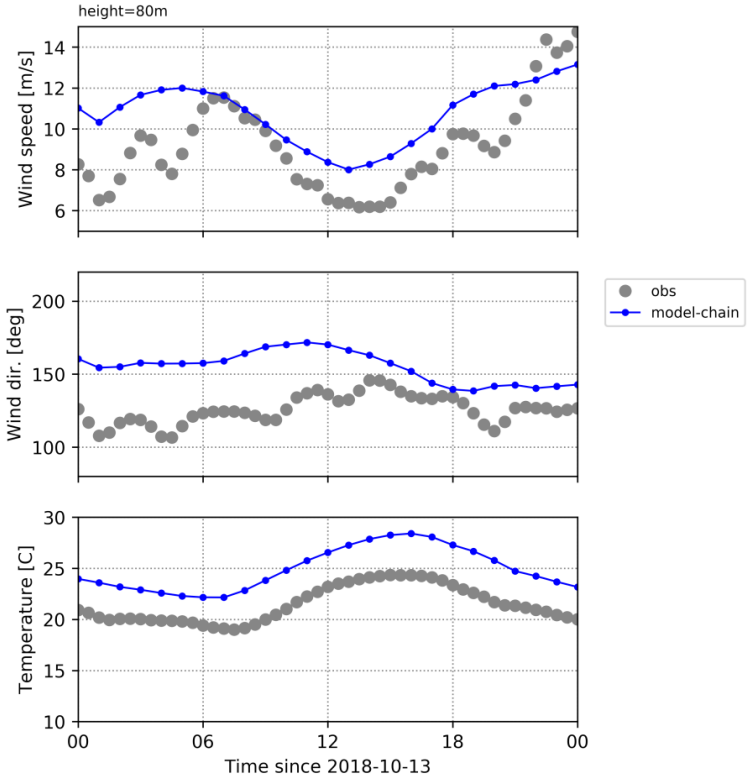
** The forest height and PAD data were generated by Ebba Dellwik DTU (Boudreult et al. 2015. Agr Forest Meteorol 201 (2015) 86–97)*

Open methodology | Open Source | Open Data

A glimpse of model-chain results

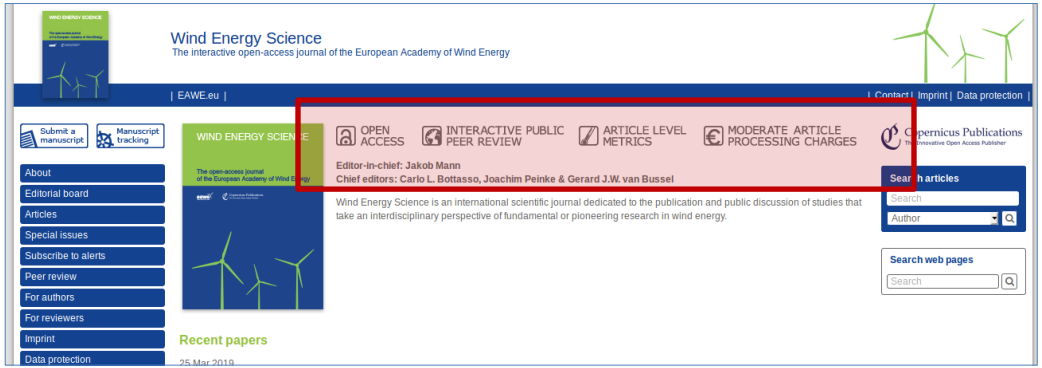


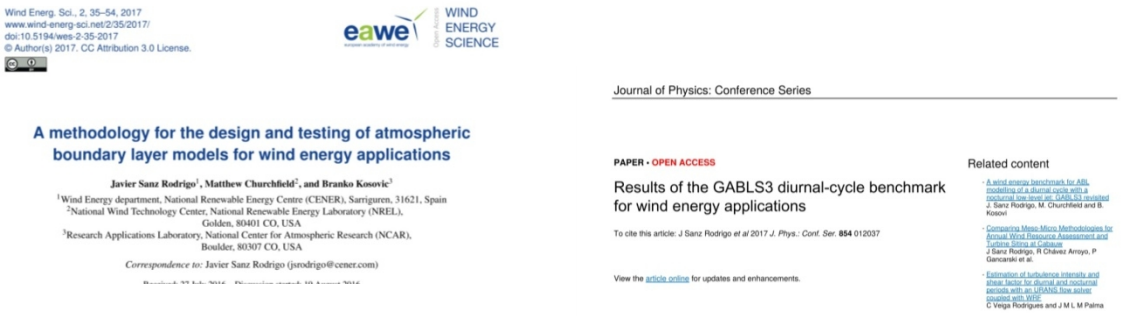
Comparison of model and measurements at Elortz1 mast at 80m height

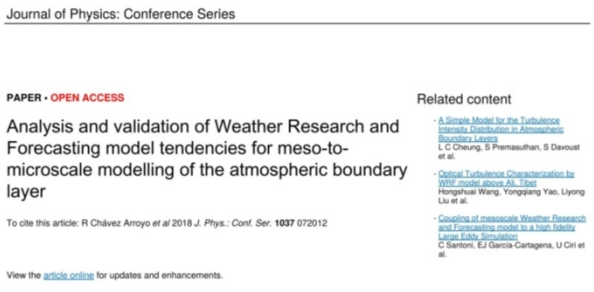


Open methodology | Open Source | Open Data | Open Access

Publication of the new method, results and V&V exercises are published in open-access journals







- https://www.wind-energ-sci.net/2/35/2017/
- https://iopscience.iop.org/article/10.1088/1742-6596/1037/7/072012
- https://iopscience.iop.org/article/10.1088/1742-6596/854/1/012037

Final comments and conclusions

- ✓ A method for addressing the meso-microscale coupling was presented.
  - More realistic physics.
  - The method is characterized by a **volumetric forcing as opposed to idealized forcing**.
  - The V&V of the method/CFDWind3 model is being carried out with ALEX17 experiment.

- ✓ The whole procedure is framed by the open-science philosophy: the method is published in open-access journals, the model-chain implementation is open-source and the validation data is open.
  - The whole philosophy makes research more **rigorous, reproducible and transparent**.
  - Clear benefits of open-science for industry is **standardization** and building **credibility** in new methods and their V&V procedures.
  - For developers of proprietary software, this is also creates a framework for model **development, validation and building trust** in their solutions.

Final comments and conclusions

ALEX17 benchmark will be open to all interested participants. Check at:
https://
thewindvaneblog.com/newa-meso-micro-challenge-phase-2-complex-terrain-98efeb03a23a

The experimental data sets are stored in the NEWA server.

The open-source model is available at the following git repository and it is indented to be a live code.
https://github.com/iat-cener/CFDWind

The evaluation methodology of the benchamarks as well as the data processing of the experiment are also available in public domain at the following links.
https://github.com/windbench/gabls3
https://github.com/windbench/NEWAMesoMicroChallengePhase1

Acknowledgements

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- Department of Economy, Science and Innovation Flemish Government (Belgium)
- Danish Energy Authority (Denmark)
- Federal Ministry for the Economic Affairs and Energy, on the basis of the decision by the German Bundestag (Germany)
- Latvijas Zinatnu Akademija (Latvia)
- Fundação para a Ciência e a Tecnologia (Portugal)
- Ministerio de Economía y Competitividad (Spain)
- The Swedish Energy Agency (Sweden)
- The Scientific and Technological Research Council of Turkey (Turkey)